Completely ordered polytypes were observed in natural crystals only for $W = 2$, and in synthetic crystals only for $W = 1$. The temperatures of formation of the natural specimens are not known, but the Aberdeenshire specimen, which contained P∞21 polytype, occurred in a metamorphic region, with considerable evidence of high-temperature products. The results therefore suggest the possibility of a low-temperature xonotlite with $W = 2$, and a high-temperature form with $W = 1$. Consideration of the central row of calcium atoms, in each triple row parallel to b, shows that each calcium has one hydroxyl ion co-ordinated where $W = 2$ while two and no hydroxyls alternate where $W = 1$. Taylor and I have shown[7] that similar rows of calcium atoms in foshagite have equal co-ordination of hydroxyl ions, possibly because of forces owing to the relative polarizations of Ca—OH and Ca—OSi bonds. The present investigation suggests that such forces may be dominant at lower, but not at higher, temperatures of formation for xonotlite. In order to test this hypothesis, samples of xonotlite will be prepared with very long reaction times at various temperatures, and data on the natural localities will be examined for evidence of formation temperatures.

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PHYSICS

Piezoelectric Effect in Poly-γ-methyl-L-glutamate

THIS communication presents some experimental evidence illustrating the piezoelectric effect in certain synthetic polypeptides.

It has been recently established that a number of high polymeric substances show a piezoelectric effect[1,2]. The substances so far investigated have been naturally occurring polymers such as cellulose, keratin, silk fibroin and collagen. Actual specimens used in the study have been taken from wood[3–5], wool[6], silk[7], bone[8–10] and tendon[11].

The effect can be accounted for by taking into consideration the crystal symmetry and unidirectional orientation of crystallites of such polymers. It seems likely that the origin of piezoelectricity in cellulose and protein results from the abundance of hydrogen bonds in their crystal structure. Until now, the piezoelectric effect in synthetic polypeptides—in which the hydrogen bond plays an essential part in determining its molecular configuration and crystal structure—has not been investigated.

Thin films of poly-γ-methyl-L-glutamate were kindly provided by the Ajinomoto Chemical Co., Tokyo. The film was stretched to twice its original length, and this resulted in a thickness of about 0·025 mm. The electrodes, each with a diameter of 10 mm, were fixed on either side of circular films of 20 mm diameter by painting them with silver paste. One end of the film was clamped to a small metal bar connected to the centre of an electromagnetic vibrator and the other to a frame which could be adjusted so as to give an appropriate tension to the film. Through two thin, flexible silver foils attached to the electrodes, the electric signal was led to a differential amplifier and then to a synchroscope.

If a longitudinal vibration was applied to the film by the electromagnetic transducer, an electrical polarization with the same frequency as that of the mechanical vibration was produced on the faces of the film and could be presented on the vertical axis of the synchroscope. If a voltage proportional to the coil current in the electromagnetic transducer was applied to the y axis of the synchroscope, a Lissajous figure, showing the relationship between stress and polarization of the specimen, was observed. During measurement, the circular film was rotated to various angles to the oriented direction so that the stress could be applied in different directions.

The apparent piezoelectric modulus d, which is the coefficient connecting the electrical polarization and mechanical stress, is plotted in Fig. 1 against the angle θ between the direction of stress and the orientation axis. The points are the average of experimental results for two films. The curve is well represented by a formula $d = d_{max} \sin 2\theta$, as would be expected for such unidirectionally oriented substances. The absolute value of the piezoelectric modulus d_{14} for these films of poly-γ-methyl-L-glutamate is $2{\cdot}8 \times 10^{-8}$ C.G.S.E.S.U., which is about half the d_{11} coefficient of quartz crystal.

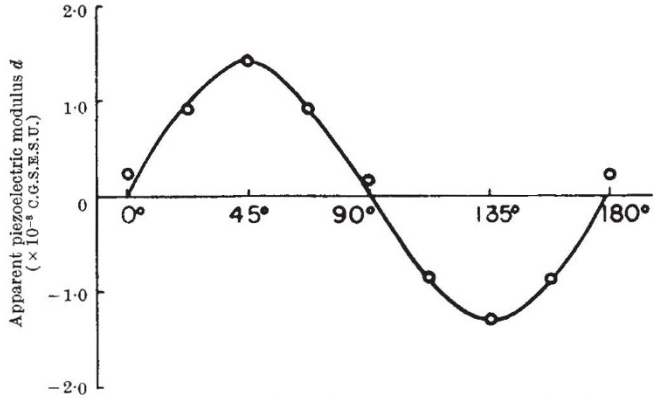

Fig. 1.

It is significant that the value of piezoelectric modulus is fairly large. This substance does not absorb water because methylation of the acidic group occurs. The molecular conformation is the α-helix form. The degree of polymerization is 3,200. The degree of crystallinity is unknown, but would be higher than 30∼40 per cent, as roughly estimated by X-ray diffraction patterns. It is believed that many synthetic polypeptides other than poly-γ-methyl-L-glutamate will also show a similar piezoelectric effect and that such studies might provide fundamental clues toward understanding the piezoelectric effect observed in a number of biological substances such as hair, bone and tendon.

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